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UPPERMOST CAMBRIAN AND LOWEST ORDOVICIAN CONODONT AND TRILOBITE BIOSTRATIGRAPHY IN NORTHWESTERN VIRGINIA

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The Shenandoah Valley in Virginia is part of the extensive Great Valley section of the Valley and Ridge physiographic province. The Great Valley is eroded, folded Cambrian through Middle Ordovician carbonate rocks and Upper Ordovician fine-grained siliciclastic lithologies. Studies by Sando (1957, 1958) established the stratigraphic position of the Cambrian-Ordovician boundary in the Great Valley carbonates of south-central Pennsylvania and western Maryland, but the position of this systemic boundary in Virginia has not been documented. The preliminary results of a biostratigraphic study utilizing conodont and trilobite faunas to determine more precisely the position of the Cambrian-Ordovician boundary in the northwestern Virginia area are reported. This is a joint study and researchers are listed alphabetically; Orndorff is responsible for the conodont work, and Taylor and Traut are responsible for the trilobites.

Two sections in the Shenandoah Valley were measured and sampled (Figure 1). Conodonts and trilobites were recovered from a section along Narrow Passage Creek, 3 km southwest of Woodstock, Shenandoah

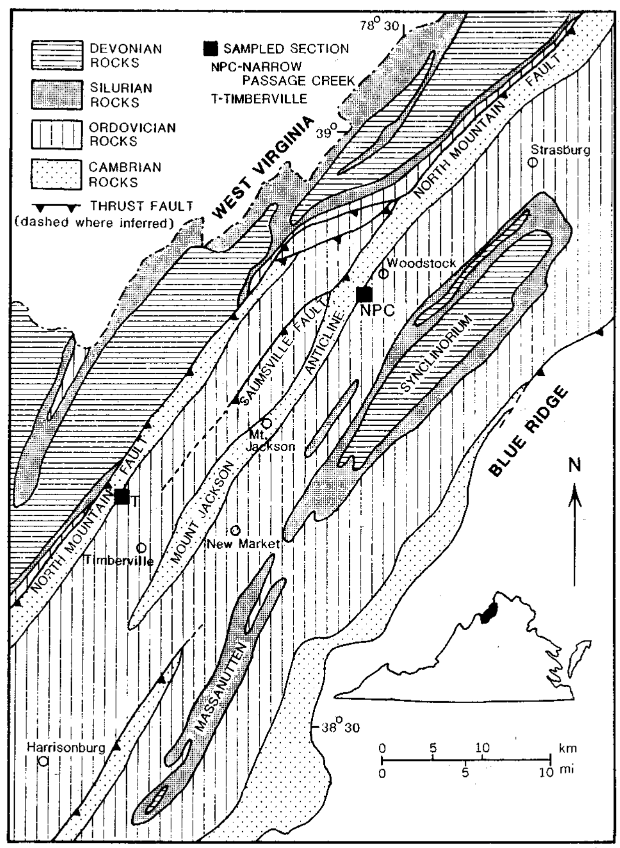

Figure 1. Generalized geologic map of part of northwestern Virginia showing the location of sections studied: NPC-Narrow Passage Creek, T-Timberville (modified from Hack, 1965).

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County. A second section along Honey Run, 4 km northwest of Timberville, Rockingham County, was sampled for conodonts; no trilobites were collected. Structurally, the sections lie west of the Massanutten synclinorium and east of the North Mountain fault. The Narrow Passage Creek section is on the east limb of the Mount Jackson anticline. The Timberville section is eastward-dipping strata on the hanging wall of the North Mountain fault.

Our objectives were to determine the lithostratigraphic position of the Cambrian-Ordovician boundary in northwestern Virginia and to document the succession of conodont and trilobite faunas through the boundary interval in this region for comparison with the successions observed elsewhere in North America.

LITHOSTRATIGRAPHY

The strata sampled in this investigation represent the upper part of the Conococheague Formation and the lower part of the Stonehenge Formation. The lithologically heterogeneous Conococheague Formation includes limestone, dolostone, sandstone, and siltstone. These lithologies occur in 5- to 12-meter-thick cycles interpreted to represent progressively shallower-water environments. Subtidal carbonates, including oolitic lime grainstone, intraclastic lime grainstone ("edgewise conglomerate"), and thrombolitic or stromatolitic lime boundstone, occur low in the cycles. Laminated dolomite and/or sandstone representing peritidal conditions cap the cycles (Demicco and Mitchell, 1982).

Laminated dolomite and oolitic lime grainstone and sandstone common in the Conococheague Formation are rare to absent in the lower part of the Stonehenge in the Great Valley. A lithology common in the Stonehenge, but not present in the Conococheague, is thick- to very thick-bedded gray to dark gray limestone with crinkly siliceous laminations. Small algal bioherms separated by channels filled with skeletal and intraclastic lime grainstone are common within the thick-bedded lithology. We tentatively place the Conococheague-Stonehenge contact in our sections at the base of the lowest interval of thick-bedded limestone with crinkly siliceous laminations. This occurs 108 meters above the base of the Narrow Passage Creek section and 82 meters above the base of the Timberville section. Sando (1957) similarly utilized the base of the "massive algal beds" as the base of the Stonehenge in mapping the Great Valley in Maryland, although he subsequently (Sando, 1958) lowered this contact, adding approximately 61 meters of thin-bedded, impure limestone to the base of the formation as the Stoufferstown Member. The limited biostratigraphic data available at present are insufficient to establish firmly whether the occurrence of the thick-bedded limestones in northern Virginia is approximately the same stratigraphic level as the base of the massive limestones in Maryland and Pennsylvania. It is possible, perhaps even likely, that the thick-bedded lithology is a biohermal facies that has its lowest occurrence at significantly different stratigraphic levels in different areas within the Great Valley.

BIOSTRATIGRAPHY

Figure 2 shows the conodont- and trilobite-based biostratigraphic units recognized in upper most Cambrian and Early Ordovician strata in North America.

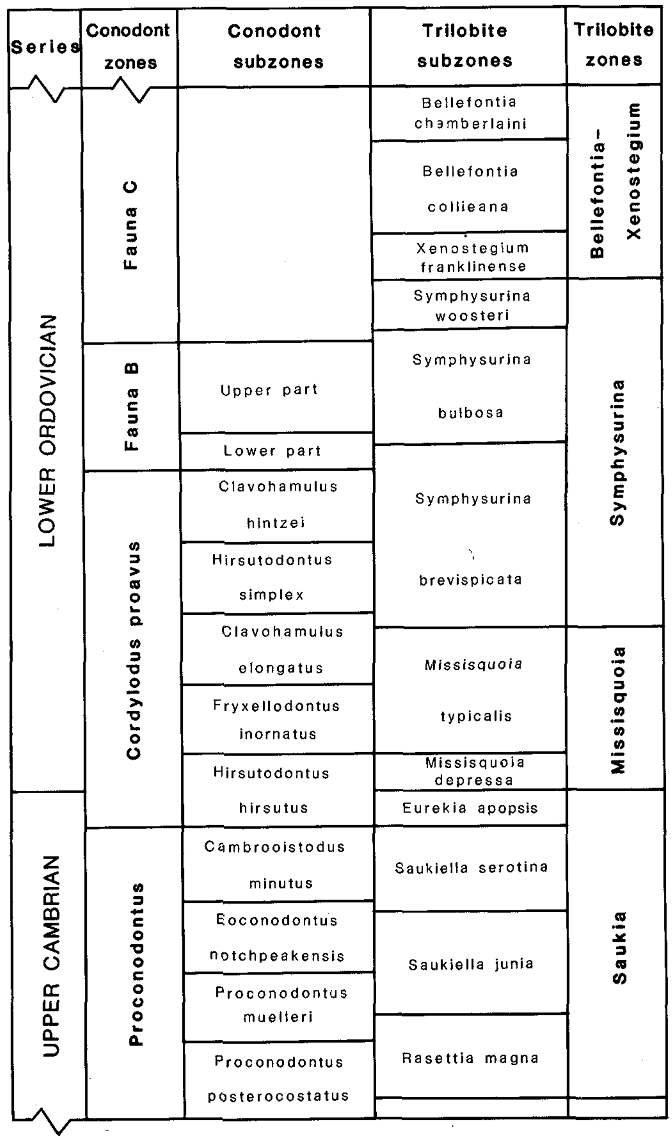


Figure 2. Conodont and trilobite biostratigraphic zones in the Upper Cambrian and Lower Ordovician of North America (after Miller and others, 1982).

Ross (1951) and Hintze (1952) described Lower Ordovician trilobite faunas from the Basin and Range Province of the western U.S. and placed the Cambrian-Ordovician boundary at the base of the *Symphysurina* Zone. Subsequently, Winston and Nicholls (1967) reported an older Ordovician fauna from central Texas and lowered the systemic boundary to the base of the newly defined *Missisquoia* Zone. This horizon presently is used as the Cambrian-Ordovician boundary in North America (Stitt, 1971, 1977; Taylor and Halley, 1974; Miller and others, 1982). Fortey (1983) proposed that *Missisquoia* Shaw is a junior synonymy of *Parakoldinioidia* Endo. Westrop (1986), however, considered this synonymy premature given the limited information presently available concerning morphologic variability within *Parakoldinioidia.* We share Westrop's opinion that a decision regarding the relationship of *Parakoldinioidia* and *Missisquoia* should be deferred pending additional study of type material of *Parakoldinioidia.* Consequently, we employ the more familiar name, *Missisquoia,* for the genus in question and the biostratigraphic units characterized by species of that genus.

As shown in Figure 2, the base of the trilobite *Missisquoia* Zone falls within the lowest subzone of the conodont *Cordylodus proavus* Zone. The base of the *C. proavus* Zone, which corresponds with the base of the *Eurekia apopsis* trilobite Subzone, provides a good approximation of the Cambrian-Ordovician boundary in sections or intervals where trilobites are scarce or lacking. Similarly, the base of the *Hirsutodontus simplex* Subzone of the *C. proavus* Zone is only slightly younger than the base of the *Symphysurina* Zone. We use the lowest occurrence of *Utahconus utahensis* (Miller), a conodont species that does not occur below the base of the *H. simplex* Subzone, to estimate the stratigraphic position of the *Missisquoia - Symphysuriana* Zone boundary in the Narrow Passage Creek section. The lowest occurrence of *U. utahensis* in that section appears to correspond closely with the Conococheague-Stonehenge formational boundary.

Conodont Faunas

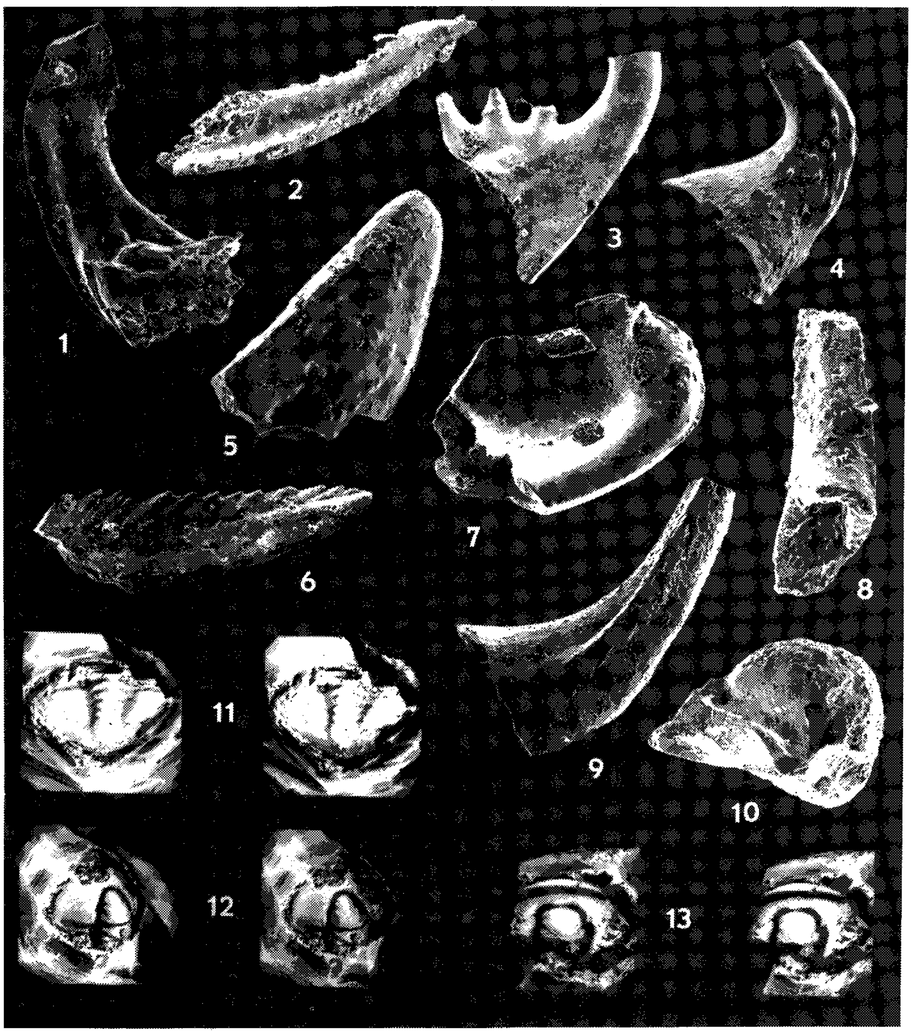
Conodonts recovered from northwestern Virginia (Plate 1; Figures 3, 4) represent several faunas of the North American Midcontinent Province. The cratonic and miogeoclinal faunas obtained are those characteristic of (from oldest to youngest) the *Proconodontus* Zone, the *Cordylodus proavus* Zone, Conodont Fauna B, and Conodont Fauna C. The lowest occurrence of one or more diagnostic species defines the base of each zone. For a thorough discussion of Upper Cambrian and Lower Ordovician conodont biostratigraphy in North America see Miller and others (1982).

Proconodontus Zone: Conodont collections from the *Proconodontus* Zone characteristically contain species of *Proconodontus* and *Cambrooistodus,* two genera that do not range upward into the *C. proavus* Zone or younger strata. A possible exception is *Proconodontus muelleri* Miller which, in a few instances, has been reported in association with *C. proavus* faunas (J. F. Miller, written communication, 1986). *Proconodontus serratus* Miller and species of *Cambrooistodus* do not occur in rocks younger than the *Proconodontus* Zone. Conodont collections from the Narrow Passage Creek section (NPC) allow recognition of the two youngest subzones of the *Proconodontus* Zone. Samples from NPC-5 to NPC-58 (5 to 58 meters above the base of the section) yielded conodonts characteristic of the *Eoconodontus notchpeakensis* Subzone of the *Proconodontus* Zone (Figure 3). The lowest occurrence of *Cambrooistodus minutus* (Miller) at NPC-58.5 marks the local base of the overlying *Cambrooistodus minutus* Subzone. The *C. minutus* Subzone is at least 4.5 meters thick at Narrow Passage Creek.

Cordylodus proavus Zone: The lowest occurrence of *Cordylodus proavus* Müller, *Hirsutodontus hirsutus* Miller, or both, defines the base of the *C. proavus* Zone. The base of the *C. proavus* Zone in the Narrow Passage Creek section occurs 64 meters above the base of the section, 44 meters below the Conococheague-Stonehenge contact as defined in this study. Conodonts from the base of the Timberville section, 75 meters below the Conococheague-Stonehenge contact, include *H. hirsutus* indicating that the base of the *Cordylodus proavus* Zone lies below the base of that section.

Miller (1978, 1980) recognized five subzones within the *C. proavus* Zone. The small size of many collections from the Narrow Passage Creek and Timberville sections, combined with low relative abundances of key taxa for some subzones, make precise delineation of subzonal boundaries within the *C. proavus* Zone difficult or impossible. Some collections from Narrow Passage Creek, however, can be assigned to particular subzones of the *C. proavus* Zone. Sample NPC-65 yielded specimens of *Clavohamulus elongatus*? (Miller), *Fryxellodontus inornatus* Miller, and *F. lineatus* Miller. The association of these three conodonts indicates that this horizon is within the lower part of the *Clavohamulus elongatus* Subzone. *C. elongatus* is not known to occur lower than the base of that subzone; both *Fryxellodontus* species range upward only into the lowest part of the *C. elongatus* Subzone.

Conodont Fauna B: Ethington and Clark (1971) recognized Fauna B above the *Cordylodus proavus* Zone. The lowest occurrence of *Cordylodus lindstromi* Druce and Jones usually defines the lowest occurrence of



EXPLANATION OF PLATE 1

Conodonts and trilobites from the Conococheague and Stonehenge Formations, Narrow Passage Creek (NPC) and Timberville (T) sections, northwestern Virginia. Figures 1-10 are SEM photomicrographs of conodont specimens: Figures 11-13 are stereo pair optical photomicrographs of magnesium oxide coated trilobite specimens. Illustrated specimens are reposited in the collections of the U.S. National Museum (USNM), Washington, D. C.

Figures

1, 2. *Proconodontus serratus* Miller. Inner lateral view of two specimens. Figure 1, USNM 413589, x100, NPC-59. Figure 2, USNM 413590, x90, NPC-5.

3. *Cordylodus proavus* Müller. Lateral view of rounded element, x90. USNM 413591, NPC-65.

4. *Hirsutodontus hirsutus* Miller. Lateral view, x100. USNM 413592, NPC-65.

5. *Fryxellodontus lineatus* Miller. Outer lateral view, x125. USNM 413593, NPC-65.

6. *Loxodus bransoni* Furnish s.f. Lateral view, x80. USNM 413594, T-107.

7. *Fryxellodontus inornatus* Miller. Inner lateral view, x100. USNM 413595, NPC-65.

8, 9. *Utahconus utahensis* Miller. Oblique posterior view of bicostate elements. Figure 8, USNM 413596, x215, NPC-108. Figure 9, USNM 413597, x178, T-45.

10. *Clavohamulus elongatus*? (Miller). Posterlateral view, x110. USNM 413598, NPC-65.

11. *Symphysurina bulbosa* Lochman. Dorsal view of exfoliated medium-sized pygidium showing characteristic inflated terminal piece, x2. USNM 413599, NPC-174.

12. *Clelandia* cf. *C. texana* Winston and Nicholls. Laterally oblique dorsal view of testate medium cephalon showing characteristic glabellar furrows and short (sagittal) frontal area, x2.5. USNM 413600, NPC-176.

13. *Hystricurus millardensis* Hintze. Dorsal view of testate medium cranidium showing distinctive anteriorly tapering gabella and fossulae, x1.7. USNM 4135601, NPC-160.

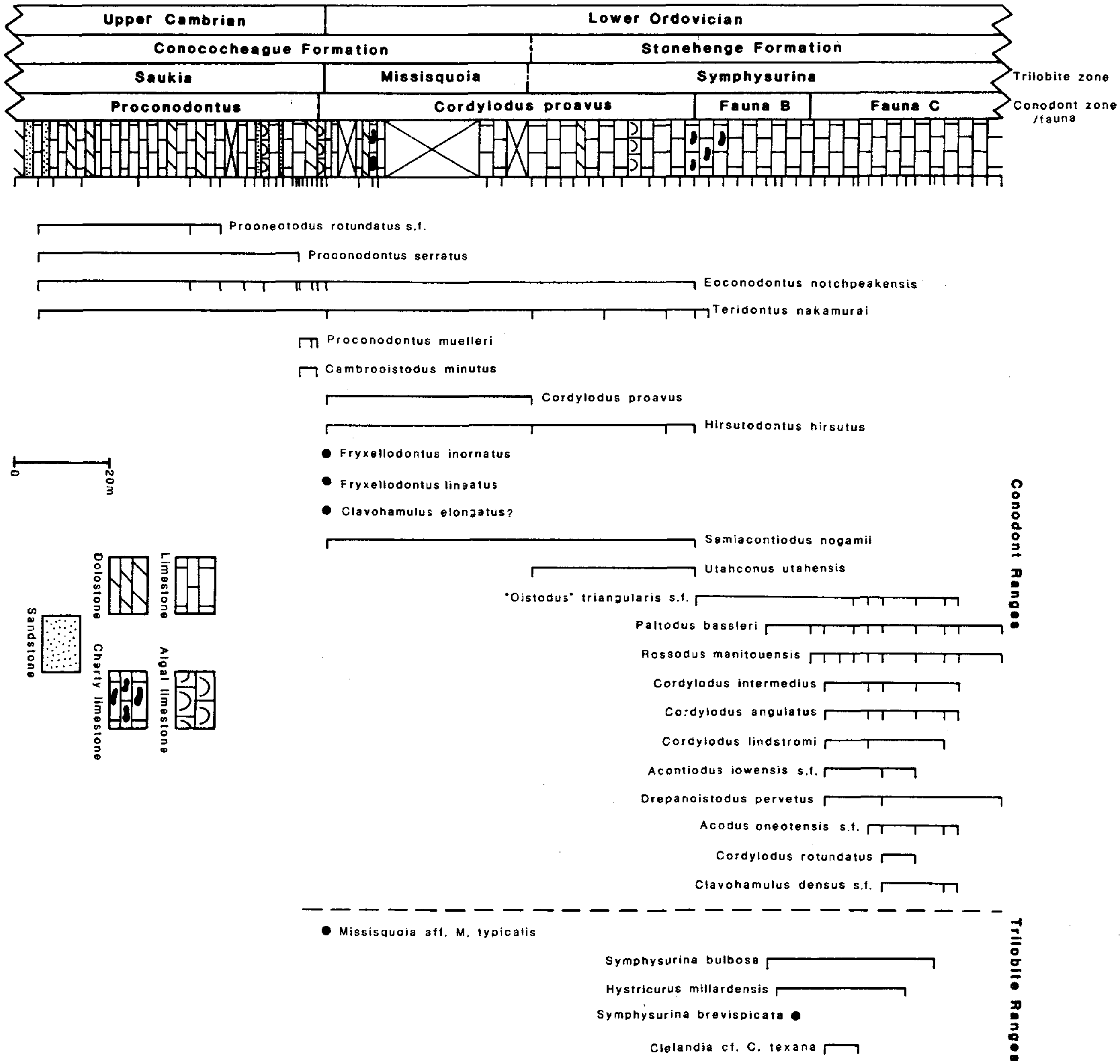


Figure 3. Ranges of selected conodont and trilobite species in the Narrow Passage Creek section.

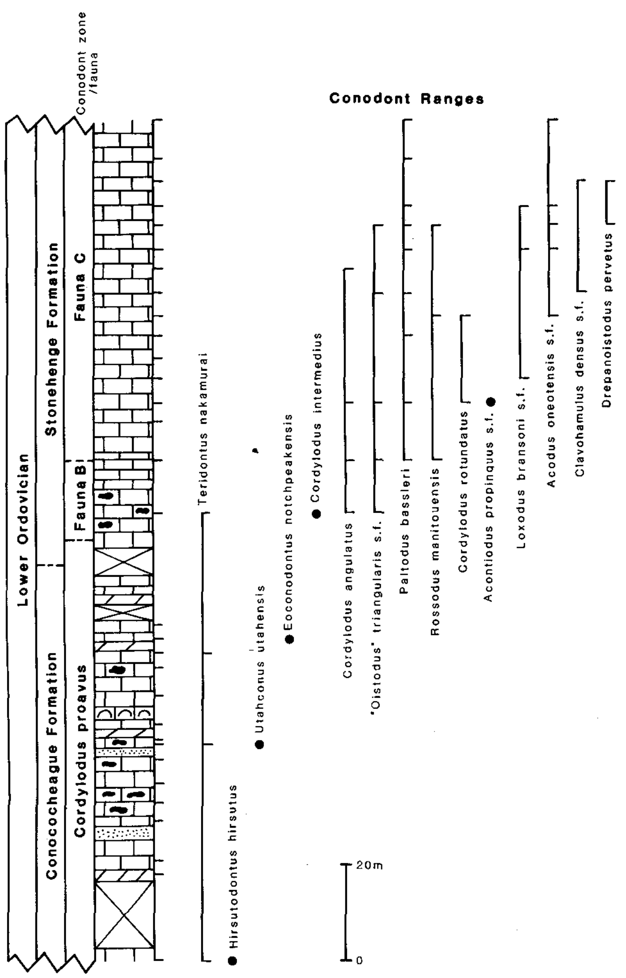


Figure 4. Ranges of selected conodont species in the Timberville section.

Fauna B; in both the Narrow Passage Creek and Timberville sections, however, *Cordylodus lindstromi* first occurs in association with species characteristic of Conodont Fauna C. Consequently, the stratigraphic interval characterized by Fauna B is recognized by using other conodont species indicative of the interval. At Narrow Passage Creek the first occurrence of *Oistodus? triangularis* Furnish s.f. at NPC-142 marks the lowest occurrence of Fauna B. Also, this same horizon marks the highest local occurrence of *Hirsutodontus hirsutus*, which ranges upward to approximately the base of the interval characterized by Fauna B. *Oistodus? triangularis* also defines the lowest occurrence of Fauna B in the Timberville section at T-90. Sample T-93 yielded *Cordylodus angulatus* Pander which characterizes the upper part of Fauna B.

Conodont Fauna C: *Loxodus bransoni* Furnish s.f. is characteristic of Conodont Fauna C (Ethington and Clark, 1971). However, *Loxodus bransoni* is not particularly abundant. Consequently, *Rossodus manitouensis* Repetski and Ethington, another important component of Fauna C (Repetski and Ethington, 1983), was used to establish the lowest occurrence of this fauna in the Narrow Passage Creek and Timberville sections. *Rossodus manitouensis* first occurs at NPC-169 and T-104. The tops of both sections are within the interval characterized by Fauna C.

Trilobite Faunas

Trilobites collected from near the base of the Stonehenge at Narrow Passage Creek (Figure 3) include species of three genera characteristic of the Lower Ordovician *Symphysurina* Zone: *Symphysurian, Clelandia,* and *Hystricurus.* Stitt (*in* Miller and others, 1982; 1983) subdivided the *Symphysurina* Zone into three subzones based on the lowest occurrences of distinctive species of that genus (Figure 2). Our study provided an opportunity to test the applicability of this new subzonation, which is based on data from areas of western North America, in the central Appalachians.

Trilobites from the lower part of the Stonehenge at Narrow Passage Creek (Figure 3) include *Symphysurina brevispicata* Hintze, *S. bulbosa* Lochman, *Hystricurus millardensis* Hintze, and *Clelandia* cf. *C. texana* Winston and Nicholls. These four species occur together in the *S. bulbosa* Subzone and in the lower part of the overlying *S. woosteri* Subzone. The absence of *S. woosteri* Ulrich (*in* Walcott, 1924), which has been reported from the Stonehenge in Maryland (Sando, 1957), and *Hystricurus hillyardensis* Stitt suggests that the highest trilobite collections from the Stonehenge at Narrow Passage Creek represent the *Symphysurina bulbosa* Subzone rather than the *S. woosteri* Subzone.

Elsewhere in North America, strata assigned to the *S. bulbosa* Subzone yield conodont species of Fauna B and Fauna C (Miller and others, 1982). Our data (Figure 3) document this same association in the Narrow Passage Creek section. Similarly, the lowest ocurrence of the conodont genus *Fryxellodontus* in other areas of North America typically corresponds with the base of the *Missisquoia typicalis* Subzone of the *Missisquoia* Zone. Strata containing *M. typicalis* Shaw and similar species of that trilobite genus commonly yield *Fryxellodontus inornatus* and *F. lineatus*. An oolitic lime grainstone within the Conococheague Formation at Narrow Passage Creek contains *F. inornatus* and *F. lineatus* and also provided an incomplete pygidium. The pygidium is fragmentary but the configuration of the steeply downsloping pleural fields, distinct anterior pleural segments terminating in marginal spines, deeply impressed pleural furrows, and only moderately impressed interpleural furrows identify it as *M. typicalis* or a similar species of *Missisquoia.*

CONCLUSIONS

The succession of conodont and trilobite faunas through the Cambrian-Ordovician boundary interval in northwestern Virginia is similar to that observed elsewhere in North America. Conodont data document firmly the stratigraphic progression from the *Proconodontus* Zone upward through the *Cordylodus proavus* Zone, Conodont Fauna B, and Conodont Fauna C. Some collections can be assigned to specific subzones; the subzones recognized in this study include the *Eoconodontus notchpeakensis* and *Cambrooistodus minutus* Subzones of the *Proconodontus* Zone and the *Clavohamulus elongatus* and *Hirsutodontus simplex* Subzones of the *Cordylodus proavus* Zone. We consider it likely that processing of additional material would result in delineation of other conodont subzones recognized in this interval elsewhere.

The more limited trilobite data verify the presence of the *Missisquoia* Zone and the *Symphysurina* Zone in the upper Conococheague and lower Stonehenge Formations, respectively. The association of *Symphysurina bulbosa, S. brevispicata, Hystricurus millardensis,* and *Clelandia* cf. *C. texana* in a 35-meter interval near the base of the Stonehenge Formation at Narrow Passage Creek allows the assignment of these strata to the *Pymphysurina bulbosa* Subzone of the *Symphysurina* Zone. This constitutes the first report of this subzone from the central Appalachian region and demonstrates that at least some of the subzones established for the *Symphysurina* Zone in western North America (Stitt, 1983) also can be recognized and utilized in the central Appalachians. The occurrence of *Fryxellodontus lineatus, F. inornatus,* and *Missisquoia* aff. *M. typicalis* approximately 43 meters below the Conococheague-Stonehenge formational contact in the Narrow Passage Creek section documents that the North American Cambrian-Ordovician boundary, that is, the base of the *Missisquoia* Zone, lies within the upper part of the Conococheague Formation in the Shenandoah Valley of northwestern Virginia.

The Cambrian-Ordovician Boundary Working Group of the International Subcommission on Stratigraphy, International Union of Geological Sciences, is selecting an international standard (boundary stratotype) for this systemic boundary. It is likely that a horizon somewhat younger than the base of the *Missisquoia* Zone will be designated (Derby, 1986). One horizon being considered is the base of the *Hirsutodontus simplex* Subzone of the *Cordylodus proavus* Zone (Figure 2), a horizon that our data suggest occurs very near the Conococheague-Stonehenge contact. Therefore, it is quite possible that, in an international sense, the Conococheague and Stonehenge Formations will most appropriately be assigned to the Cambrian and Ordovician Systems, respectively, the contact between these formations in northern Virginia closely approximating the stratigraphic position of the international Cambrian-Ordovician boundary.

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